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[DATA RECONSTRUCTION METHOD AND SYSTEM EMPLOYING THE SAME]

DATA RECONSTRUCTION METHOD AND SYSTEM WHEREIN TIMING
OF DATA RECONSTRUCTION IS CONTROLLED IN ACCORDANCE
WITH CONDITIONS WHEN A FAILURE OCCURS

Now U.S. Patent No. 5,941,953

Now U.S. Patent No.
5,889,938

CROSS-REFERENCES TO RELATED APPLICATIONS

This is a continuation of application Serial No. 08/895,682 filed on July 17, 1997, which is a continuation of application Serial No. 08/534,841 filed on September 27, 1995, which is a continuation of

- 1 BACKGROUND OF THE INVENTION application Serial No. 071859,850 filed on March 30, 1992, now U.S. Patent No. 5,495,572.
- The present invention relates to a memory for performing access or read/write in parallel with a plurality of independent storage units as a set, and
- 5 more particularly to a data reconstruction system and a method used therein which are available in occurrence of a failure.

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10 The technology for controlling discs arranged corresponding in parallel is disclosed in JP-A-H1-250128 [corresponds] to U.S. Patent Application Serial No. 118,785 filed on November 6, 1987, and JP-A-H2-135555.

15 As for the technology for achieving the large capacity of a memory and the high speed transfer of data, there is known a method in which the data is divided into a plurality of data of bit units, byte units or arbitrary units with a plurality of storage units as a set, to be stored in the respective storage units, and when the data is to be read out, the plurality of data is simultaneously read out from the respective storage units. Moreover, in this method, the data to be used for a parity check is produced from the data divided among the storage units to be stored in another storage unit. When the failure occurs in any of the storage units, the data stored in the remaining normal storage units and the data for the parity check are used to

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in parallel is disclosed in Japanese Kokai 1-250128 corresponding to U.S. Patent Application Serial No. 07118,785 filed on November 6, 1987, and Japanese Kokai 2-135555. Now U.S. Patent No. 4,870,643

1 reconstruct the faulty data, thereby to improve the reliability of the memory.

Further, there is known the technology in which when the failure occurs in any of the storage 5 units, not only the data is reconstructed for the normal read operation, but also the data stored in the storage unit at fault is reconstructed to be stored in the normal storage unit which is additionally provided.

With this technology, the reconstructed data is stored 10 in the spare storage unit and the data is read out from the spare storage unit for the subsequent access, whereby it is possible to improve the availability of the memory.

The failure of a certain number of storage 15 units can be repaired by providing the parity data, and the data can also be reconstructed by the provision of the spare storage unit. However, for the operation of repairing the failure, it is necessary to read out all 20 of the data stored in the normal storage units and the data for the parity check, reconstruct the faulty data and write the reconstructed data to the spare storage unit. Therefore, during the repair of the failure, the storage units are occupied so that the request to process the normal access or read/write which is issued 25 from a host unit continues to wait. This results in the degradation of the performance of the memory. As for the error check method for reconstructing the faulty

1 data, there are known the parity data, [the] Reed-Solomon
2 code and error check code (ECC) method,
3 [Code and the error check code (ECC).]

Although the redundancy is provided for the failure of a plurality of storage units, the failure
5 repair in the failure of one storage unit and that in the failure of a plurality of storage units are managed without taking the distinction therebetween into consideration. Therefore, putting emphasis on the repair of the failure, since the processing of the
10 normal access or read/write cannot be performed ^{in spite} [inspite] of the failure of one storage unit, there arises a problem in that the efficiency of the processing of the normal access or read/write is reduced. On the other hand, putting emphasis on the normal access or
15 read/write operation, there arises a problem in that the time required for the repair of the failure is not secure during the failure of a plurality of storage units, and as a result, the possibility that the whole system may break down will be increased.

20 SUMMARY OF THE INVENTION

It is therefore an object of the present invention to minimize the reduction of the processing of the normal access or read/write in the failure, limit the time required for the repair of the failure within a
25 fixed period of time, and ensure the high reliability, with respect to a memory which has the redundancy for the failure of two or more storage units.

1 It is another object of the present invention
to provide a data reconstruction system which is capable
of selecting a suitable data reconstruction method in
correspondence to the various kinds of conditions
5 relating to the repair of the failure and carrying out
the most suitable data reconstruction processing.

It is still another object of the present
invention to provide a control system which is capable
of changing the procedure of data reconstruction
10 processing in correspondence to the change of redundancy
relating to the number of ECC discs included in a
plurality of storage units which are arranged in
parallel to one another.

The above objects of the present invention are
15 attained by the provision of a memory ^{including} comprising: a
group of storage units for ^{dividing} [striping] data into a
plurality of data of bit ^{units, byte units} unit, bite unit or arbitrary
^{unit} unit to store therein the ^{divided} [striped] data, the plurality of
independent storage units forming a set; discs for
20 storing therein ECC data corresponding to the ^{divided} [striped]
data; a spare storage unit for storing therein the
reconstructed data; an I/O-reconstruction control
circuit for receiving a command relating to ^{an I/O operation} [I/O] issued
from a host unit to execute processing in accordance
25 with the command or respond to the host unit; a timer
for giving the point of failure, an elapsed time during
the data reconstruction, a unit time and the like; a
data reconstructing table for the storage unit at fault;

1 and a faulty data reconstructing circuit for performing
discovery of the faulty data, data reconstruction and an
operation of writing data to a spare storage disc,
wherein when a failure occurs in any of the storage
5 units, the faulty data reconstructing circuit detects
the failure by an error check to inform the I/O-
reconstruction control circuit of the failure, and the
I/O-reconstruction control circuit discriminates a state
of the failure to select the preferred processing
10 suitable for the state of the failure out of the
processing of the normal access or read/write and the
data reconstruction processing, thereby to execute the
selected processing, or set the frequency of the
processing of the normal access or read/write and the
15 data reconstruction, or the ratio of the [processing]
amount of the data reconstruction within a unit time.
1 [amount.]

When the failure occurs in the above memory,
the redundancy of the memory, the elapsed time during
the data reconstruction, and the state of the normal
20 access or read/write processing and the like are
discriminated, and the data reconstruction processing
(method) suitable therefor is selected. Therefore, it
is possible to prevent reduction of the performance of
the processing of the normal access or read/write and
25 ensure the high reliability of the memory. More
specifically, in the case where the number of storage
units at fault [has a room for] ^{as less than} the redundancy of the
memory, there is selected the data reconstruction

- 1 processing (method) in which the processing of the
normal access or read/write is given preference, and the
faulty data is reconstructed within the remaining period
of time. Therefore, no load is put on the processing of
5 the normal access or read/write. On the other hand, in
the case where there is no [room in the] redundancy, since
the processing of reconstructing faulty data is given
preference, it is possible to ensure the reliability for
the failure of the memory. Moreover, in the case where
10 there is [a room in the] redundancy, since the data
reconstruction processing (method) is changed according
to the magnitude of the ~~accumulating totals~~ of time
which was taken to repair the failure with respect to
the storage units in which the failure occurred, it is
15 possible to prevent reduction of the performance of the
processing of the normal access or read/write and limit
the time required for the data reconstruction within a
fixed period of time. Moreover, [the] time zone, e.g.,
[the] night, having less processing of the normal access or
20 read/write is selected so that the system can devote
itself to the data reconstruction. As a result, it is
possible to reduce the load of the memory in [the] time
zone having much processing of the normal access or
read/write. Moreover, since the frequency of the data
25 reconstruction processing, or the ratio of the amount of
data reconstruction ^{within unit time} is set according to the magnitude of
the frequency of the processing of the normal access or

1 read/write, it is possible to carry out the data
reconstruction processing effectively in a time aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flow chart of the processing of
5 reconstructing faulty data according to the present
invention;

Fig. 2 is a block diagram showing the
arrangement of a memory according to the present
invention;

10 Fig. 3 is a diagram showing the arrangement of
a data reconstructing table for a disc at fault of the
present invention;

Fig. 4 is a flow chart showing the processing
employed in the memory of Fig. 2;

15 Fig. 5 is a flow chart of a block of selecting
the data reconstruction processing in Fig. 4;

Fig. 6 is another flow chart of a block of
selecting the data reconstruction processing in Fig. 4;

20 Fig. 7 is still another flow chart of a block
of selecting the data reconstruction processing in Fig.
4;

Fig. 8 is yet another flow chart of a block of
selecting the data reconstruction processing in Fig. 4;
and

25 Fig. 9 is a further flow chart of a block of
selecting the data reconstruction processing in Fig. 4.

1 DESCRIPTION OF THE PREFERRED EMBODIMENTS

The description will hereinafter be given to a flow chart showing the processing of reconstructing faulty data of Fig. 1.

- 5 It is assumed that a failure occurs in a memory or a motor (Step 10). In this connection, this failure is detected by the check of an error check code or by the check of the deviation of a motor driving voltage from a predetermined range. First, it is judged
10 whether or not the failure thus occurred is repairable (Step 20). If not, then^[] the data reconstruction processing is completed. This results in^[the] data loss (Step 30). If so, it is judged on the basis of the redundancy of the memory, the elapsed time of the data
15 reconstruction and the processing state of the processing of the normal access or read/write whether or not it is a state in which the system should devote itself to the data reconstruction (Step 40). If a request to process the normal processing such as access
20 or read/write is issued from a host unit under the condition in which there is a sufficient^{remaining redundancy} [room] and the urgency of the reconstruction is low, the data reconstruction processing is stopped and the normal processing such as access or read/write is given
25 preference. Then, the data reconstruction processing is performed within the remaining period of time, and the processing of access or read/write during the data reconstruction is cancelled or queued (Step 50).

- remaining redundancy*
- 1 Conversely, if there is no [room] and the urgency of the reconstruction is high, the data reconstruction processing is given preference, and all of the normal processing such as access or read/write is cancelled or
 - 5 queued (Step 60). Moreover, in the case of the intermediate state in which there are some combinations between the urgency of the data reconstruction and the significance of the normal processing such as access or read/write, the data reconstruction processing
 - 10 corresponding to the individual conditions is previously prepared in the form of programs. Then, when the conditions are changed, it can proceed to the suitable processing by replacing an old program with a new one. (Step 70). Next, when the data reconstruction
 - 15 processing is completed or interrupted, it is checked whether or not the data reconstruction processing still remains (Step 80). After all of the data reconstruction processing has been completed, the memory returns to the normal [state.] If the data reconstruction processing
 - 20 still remains, the flow returns to Step 20 and the above steps will be repeated until the data reconstruction is completed.

Next, the description will be given to a block diagram showing the arrangement of an embodiment of the present invention ^{will be described with reference to} Fig. 2..

In Fig. 2, the reference numeral 150 designates an I/O-reconstruction control circuit which receives a command relating to ^{an I/O operation} [I/O] issued from the host

- 1 unit to carry out the processing according to the
2 command or respond to the host unit. Further, when (the)
3 failure (is occurring) has occurred in any of the storage units, the
circuit 150 serves to select a suitable data reconstruc-
5 tion method on the basis of the number of discs during
the reconstruction, the time taken to reconstruct the
faulty data, the frequency of the data reconstruction,
8 or the amount of the data [reconstruction] and the like.
There is connected to the individual storage units a
10 monitor 155 which monitors [that] after the power source
for driving the storage units is activated, the driving
voltage is in a predetermined range, and feeds a pseudo-
12 instruction for reading out [the] data previously stored
13 in a predetermined location to the storage units which are entering
14 into the running state [to monitor] the responses sent
15 therefrom. The reference numeral 154 designates a data
reconstructing table for the storage unit at fault of
which details will be described [below with respect] referring to Fig. 3.
The reference numeral 152 designates a clock or timer
20 for obtaining the point of failure by giving the time of
day and obtaining the elapsed time during the re-
construction and the unit time by a certain method.
Then, the data reconstruction method can be changed [with]
23 the time measured by the timer as one condition. The
25 reference numeral 156 designates a circuit for re-
constructing faulty data which performs the discovery of
the faulty data, the data reconstruction and the [writing]
7 of the data to a spare storage disc. Moreover, the

1 circuit 156 reads out the data from all of the discs
except the disc at fault, reconstructs the faulty data
using the data thus read out, and transfers the
reconstructed data to the host unit and writes it to the
5 spare storage disc. The reference numerals [158 to] 168
designate a group of data discs for storing therein the
[striped] ^{divided} data. Although [the six] discs are shown [as the]
[data discs] in Fig. 2, the number thereof is generally
arbitrary. The reference numerals 170 and 172 designate
10 discs which store therein [the] ECC data corresponding to
the [striped] ^{divided} data which is stored in the [discs 158 to] 168,
11 and
14 When the failure occurs, the faulty data is
reconstructed using the ECC data and the normal data
15 redundancy [which the memory has] corresponds to the
number of ECC discs with respect to the number of discs
17 up to a certain number. But, in the case where [the]
18 more than a certain number of the discs break down,
19 [discs break down of which number is more than that]
20 [certain number,] it is impossible to reconstruct the
21 faulty data. This results in [the] data loss. Fig. 2
22 shows that [even] when the number of ^{when} ~~discs~~ ^{data} is two,
23 [i.e., the] two data discs break down, the faulty data can
be reconstructed. However, since there is generally
24 known [the] ECC production method which ^{can compensate for} stands up to the
25 failure of two or more discs, the number of faulty discs
which does not result in [the] data loss, i.e., the
26 redundancy, can be increased. The ECC production is
27 concretely realized using the Reed-Solomon ^{code} [Code.] The

- 1 Reed-Solomon ^{Code} [Code] and the error correction method employing the same themselves are well known. The reference numerals 174 and 176 designate spare storage ^{units} ₁ for storing therein the reconstructed data. Then,
- 5 in the case where the storage contents of the faulty disc are stored in ^a [the] spare storage ^{disc} ₁ unit, that spare storage ^{disc} ₁ unit is accessed with the data stored therein after the next time. The number of ^{spare storage discs} ₁ those discs is generally arbitrary.

10 The [description will now be given to the] data reconstructing table for the disc at fault. ^{fault will be described with} _{reference to Fig. 3,} The data reconstructing table 154 includes the identification number of the spare storage disc (1), the identification number of the disc at fault (2), the point of failure (3), the sector or address of the ^{failure} [faulty data] (4), and the flag used to judge whether or not the failure is repairable (5).

Next, the operations of the memory of Fig. 2 and the table of Fig. 3 will be described on the basis of a flow chart shown in Fig. 4.

First, in Fig. 2, it is assumed that the failure occurs in the data disc [unit] 162 (Step 100). Then, the circuit 156 for reconstructing faulty data detects that failure ^{and informs} [to inform] the I/O-reconstruction control circuit 150 of that failure. After receiving that information from the circuit 156, the circuit 150 checks whether or not an unoccupied space is present in the data reconstructing table 154 by referring to the

- 1 table 154 (Step 102). Subsequently, the circuit 150 checks whether or not that failure is a failure which occurred in a new disc (Step 104). If so, the circuit 150 instructs the circuit 156 to write the following
- 5 initial values ~~to~~ ^{to} the columns of interest in the data reconstructing table 154 of Fig. 3. That is, the circuit 156 writes the identification number SPARE 1 of the spare disc 174 ~~to~~ ^{to} the column of the spare storage unit in the data reconstructing table 154, and writes
- 10 the identification number #2 of the data disc 162 at fault ~~to~~ ^{to} the column of the storage unit at fault. Next, the circuit 156 writes the point of failure read out from the timer 152 ~~to~~ ^{to} the column of the point of failure, and writes the failure occurrence address in
- 15 the faulty disc 162 ~~to~~ ⁱⁿ ~~the column of address.~~ ^{the sector or address of the failure,} Finally, the circuit 156 initializes the reconstruction judgement flag of each address (Step 106). If that failure is not a new one, the processing of Step 106 is not executed, but the processing proceeds to the subsequent ~~Step.~~ ^{step.} In
- 20 the subsequent ~~Step,~~ ^{step,} the circuit 150 discriminates the state of the failure, selects either the processing of the normal access or read/write, or the data reconstruction processing which is suitable for the state of the failure, and executes the selected
- 25 processing (Step 108). The details of this Step 108 will be described ^{below with reference} ~~on referring~~ to Fig. 5 to Fig. 9. Next, when the data reconstruction processing is completed or interrupted, it is checked whether or not

- 1 the data reconstruction processing still remains (Step
110). When all of the data reconstruction processing is
completed, the memory returns to the normal state. When
the data reconstruction processing still remains, the
processing returns to Step 102, [then, the above Steps]
will be repeated until all of the data reconstruction
processing is completed. [Even if] any data reconstruction
method is chosen, the circuit 156 monitors the
continuation or completion of the data reconstruction
processing. In the case where [the] subsequent failure
occurs when the data reconstruction of interest has not
yet been completed, the circuit 156 starts performing
the processing in the same manner as described above
(Step 102). Then, in the case where the number of
faulty discs (of) which data reconstruction [in] is not
completed exceeds the redundancy of the memory, since
the data reconstruction is impossible, the circuit 150
informs the host unit of [the] data loss (Step 114). If
the data reconstruction processing is completed, the
unnecessary data in the data reconstructing table 154 is
erased and the memory returns to the normal state (Step
112). The address in the table 154 may [have] a track
unit, sector units, word units, or any other unit.
Next, [the description will be given to] Step
108 of Fig. 4 [on referring] to Fig. 5.
In Fig. 5, the I/O-reconstruction control
circuit 150 counts the number of discs (of) which data
reconstruction [is not] completed by referring to the data

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- 1 reconstructing table 154, and compares the number of faulty discs with ~~the~~^a threshold (Step 120). If the number of faulty discs is less than the threshold which is previously set to a value less than or equal to the redundancy, the circuit 150 judges that ~~there is a room~~^{or equal to} ~~remaining~~^{in the} redundancy, gives the processing of access or read/write preference and performs the processing of reconstructing faulty data within the remaining period of time. All of the processing such as access or read/write during the reconstruction waits, i.e., it is cancelled or queued (Step 122). On the other hand, if the number of faulty discs is more than the threshold, the circuit 150 judges that ~~the redundancy has no room,~~^{there is no remaining redundancy}, gives the data reconstruction processing preference, and cancels or queues all of the normal processing such as access or read/write (Step 124).

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The reconstruction is performed ~~with~~^{on the basis of} a unit, such as 1 track, in which the repair and the storage are completed ~~for~~ⁱⁿ a relatively short period of time. After the completion of the reconstruction, the memory is opened for the normal processing. But, when the instruction of the processing of access or read/write is issued from the host unit during the reconstruction, the data reconstruction work is stopped immediately, and then the memory is opened for the processing of access or read/write. In the case where during the processing of access or read/write, ~~the~~ data which has not yet been reconstructed is read out, the faulty data is then

- 1 reconstructed using the ECC data and the normal data
which was used when producing the ECC data, and the
reconstructed data is sent to the host unit. At the
same time, the reconstructed data is stored in the spare
5 disc and the reconstruction judgement flag of the
address column of interest in the data reconstructing
7 table 154 is set to [the] completion of the reconstruction.
8 If this flag is set to [the] completion of the
reconstruction, the subsequent access to this data is
10 performed with the spare disc. In the case of writing
11 data, after the ECC data has been produced, the data ~~is to~~
12 ^{written normally} be stored in the faulty disc is stored in the spare
13 disc, and then the reconstruction judgement flag is set
14 to [the] completion of the reconstruction.
- 15 Since in the example of Fig. 2, the redundancy
is two, it is proper that the threshold is necessarily
set to 1. However, in the case where the Reed-Solomon
16 code capable of correcting errors in
17 multiplex dissipation
18 With two or more discs is used, the threshold may be
19 have
20 an arbitrary integral number less than or equal to the
redudancy. Those values are previously set in the
table 157.

Since the I/O-reconstruction control circuit
21 stores the address of the ^{last} data which was re-
22 constructed at the last time, the data reconstruction is
23 performed from the subsequent address. In the reconstr-
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- 1 when the flag is not set in the data reconstructing table [154, thus indicating that] the data reconstruction is not completed with respect to the subsequent address, the data [of] that address is reconstructed. The reconstruction of the data is performed in such a way that the ECC data and the normal data which was used to produce the ECC data from the normal discs are read out and the circuit 156 for reconstructing faulty data is used. The reconstructed data is written [to] the spare disc and the flag in the data reconstructing table 154 is set to [the] completion of the data reconstruction. Then, the reconstructed data in the spare disc [will] be accessed. The address of the reconstructed data is stored in the circuit 156, and the processing by the circuit 150 proceeds to the subsequent data reconstruction processing.

In the embodiment of Fig. 5, when the number of faulty discs is less than or equal to the threshold, the processing of the normal access or read/write takes precedence over the data reconstruction. Therefore, it is possible to reduce degradation of the performance of access or read/write of the memory. Moreover, since in a state in which the system devotes itself to the data reconstruction, the reconstruction can be performed [for] a short period of time, it is possible to maintain the reliability of the memory.

In the above embodiments, the data reconstruction method is selected by paying attention to only the

- 1 number of faulty discs. However, the elapsed time taken
2 to reconstruct the faulty data [can be] in addition to
3 the number of faulty discs, included in the conditions.
4 another example of
5 Next, [the description will be given to] Step
will be described with reference
5 108 of Fig. 4 [on referring] to Fig. 6.

In Fig. 6, the I/O-reconstruction control circuit 150 counts the number of discs [of] which reconstruction is not yet completed by referring to the data reconstructing table 154, and compares the number 10 of faulty discs with [the] threshold (Step 130). If that number is less than or equal to the threshold, then, the circuit 150 reads the present time from the timer 152, and compares the time taken to reconstruct the faulty data, which can be calculated from the present time and 15 the point of failure in the data reconstructing table 154, with a predetermined limit time (Step 132). Then, if the reconstruction time is less than the predetermined limit time, it is considered that [there is a room] 18. ^{meant} _{not equally} → [for] the data reconstruction can be deferred. Therefore, the circuit 150 19 → [for] the data reconstruction. Therefore, the circuit 150 20 instructs the circuit 156 for reconstructing faulty data to give the processing of the normal access or read/write preference, reconstruct the data in the faulty discs within the remaining period of time, and store the reconstructed data in the spare disc. The request to 25 perform the processing of access or read/write issued from the host unit during the reconstruction is cancelled or queued (Step 134). If the number of faulty discs is more than the threshold, or the [difference]

$t_{failure} \rightarrow t_{present}$
reconstruct?

9
10 1 [between the present time and the point of failure is]

more than the predetermined limit time, it is considered
that the data reconstruction cannot be deferred.
that there is no room for the data reconstruction.]

3 Can or can not
Therefore, the circuit 150 cancels or queues the command
5 of the normal access or read/write issued from the host
unit and instructs the circuit 156 to give the data
reconstruction preference (Step 136).

In the embodiment of Fig. 6, when the time taken to reconstruct the faulty data exceeds the limit
10 time, the system devotes itself to the processing of reconstructing faulty data. Therefore, it is possible
12 to limit the reconstruction time within ^afixed period of time and improve the reliability of the memory.

14
15 Next, ^{another example of} the description will be given to Step
108 of Fig. 4 ^{will be described with reference} referring to Fig. 7.

16 In Fig. 7, the I/O-reconstruction control circuit 150 obtains the present time from the timer 152 and judges whether or not that time is ⁱⁿ a time zone having much processing of the normal access or read/
20 write (Step 140). If not, the circuit 150 cancels or queues the command of the normal access or read/write issued from the host unit, and instructs the circuit 156 for reconstructing faulty data to give the data re-

construction preference. Moreover, even if that time is ⁱⁿ a time zone having much processing of the normal access or read/write, the time zone, when the number of faulty discs of Step

25 142 exceeds the threshold, similarly, the data reconstruction processing is given preference (Step 146).

26 Only when that time zone ^{is in a} having much processing of the

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- 3
- 1
- 1 normal access or read/write and the number of faulty discs is less than or equal to the threshold, the processing of the normal access or read/write [is] given preference and the data reconstruction [is] performed ^{within} ~~for~~
 - 5 the remaining period of time (Step 144).

In the embodiment of Fig. 7, when it is previously known that the method of using the memory depends on the time zone, the data reconstruction processing can be assigned to the time zone having less processing of access or read/write. Therefore, the data reconstruction processing can be smoothly carried out without the processing of access or read/write hindering the data reconstruction processing.

- 14
- 15 to Fig. 7, there are provided two kinds of data reconstruction processing in which the reconstruction or the processing of access or read/write is given preference. However, the kind of data reconstruction processing may be increased in correspondence to the circumstances.

- 20 Next, ^{another example of} the description will be given to Step 108 of Fig. 4 ^{will be described with reference} on referring to Fig. 8.

In Fig. 8, when the number of faulty discs exceeds the threshold in Step 180, the data reconstruction processing is given preference and the processing of the normal access or read/write is stopped (Step 188). When the number of faulty discs is less than or equal to the threshold, and ^{the time is not in} ~~it is not~~ the time zone having much processing of the normal access or

- 1 read/write in Step 182, only the read processing is performed and the data reconstruction processing is given preference for the remaining period of time (Step 186). When the number of faulty discs is less than or
- 5 equal to the threshold and ^{the time is in} [it is] the time zone having much processing of the normal access or read/write, the processing of the normal access or read/write is given preference and the data reconstruction processing is performed within the remaining period of time (Step
- 10 184).

In the embodiment of Fig. 8, when the number of faulty discs is less than or equal to the threshold, ^{the time is in} but [it is] the time zone having less processing of the normal access or read/write, especially, the time zone

15 having only the read processing, the read processing is ^{preferentially} ~~exceptionally~~ allowed to be performed, whereby it is possible to reduce degradation of the performance of the memory without hindering the data reconstruction processing.

20 Next, ^{another example of:} the description will be given to Step 108 of Fig. 4 ^{will be described with reference} _{on referring to Fig. 9.}

In Fig. 9, when the number of faulty discs exceeds the threshold in Step 190, or the number of faulty discs is less than or equal to the threshold in

25 Step 190 and the ^{time taken to reconstruct the faulty data} [accumulating totals of the data] _{reconstruction time} exceeds the limit time in Step 192, the data reconstruction processing is given preference and the processing of the normal access or read/write is

- 1 stopped (Step 202). When the number of faulty discs is
2 less than or equal to the threshold and the ~~accumulating~~
3 ~~time taken to reconstruct the faulty data~~
4 totals of the data reconstruction time is less than the
5 limit time, the I/O-reconstruction control circuit 150
6 reads ~~the~~ ^a unit time from the timer 152, and compares the
7 frequency of the processing of the normal access or
8 read/write within that unit time with ~~the~~ ^a predetermined
9 threshold (Step 194). When the frequency of the
10 processing of the normal access or read/write is more
11 than the threshold, it is considered that ~~the accumu-~~
12 ~~lation is within the limit time and there is a room for~~
13 ~~reconstruction can be deferred,~~
14 the data ~~(reconstruction.)~~ Therefore, the processing of
15 the normal access or read/write is given preference and
16 the data reconstruction processing is performed within
17 the remaining period of time (Step 196). On the other
18 hand, when the frequency of the processing of the normal
19 access or read/write is less than the threshold, ~~and~~ the
20 ~~may have any magnitude~~
21 ~~frequency thereof is limitlessly near or far from the~~
22 ~~and thus~~ threshold, the frequency changes in magnitude. There-
23 fore, the frequency of the data reconstruction proces-
24 sing or the ratio of the amount of data reconstruction
25 within the unit time is dynamically set according to the
magnitude of the frequency of the processing of the
normal access or read/write (Step 198). Then, the data
reconstruction processing is carried out according to
the frequency of the data reconstruction processing or
the ratio of the amount of the data reconstruction ^{within the unit time} thus
set (Step 200).

1 In the embodiment of Fig. 9, the frequency of
the data reconstruction processing or the ratio of the
amount of the data reconstruction is set according to
the magnitude of the frequency of the processing of the
5 normal access or read/write. Therefore, the data re-
construction processing ^{*can*} ~~will~~ be carried out effectively
in a time aspect.

8 Although ^{*the*} magnetic disc is ^{*used*} ~~given~~ as the
storage unit in the above-mentioned embodiments, the
10 present invention is not limited thereto or thereby.
That is, alternatively, an optical disc, a floppy disc,
or a semiconductor memory may be used as the storage
unit.

Moreover, as the conditions for selecting the
15 data reconstruction method, instead of the above embodi-
ments, the job contents of the host unit, the signifi-
cance of the file in the memory, and the like may be
used as the conditions. The combination of those
conditions and the data reconstruction method allows the
20 flexible data reconstruction processing to be performed.

According to the above embodiments, when the
number of storage units at fault is less than the
redundancy of the memory, the processing of access or
read/write takes precedence over the data reconstruction
25 processing. Therefore, the load of the memory is not
increased so that it is possible to reduce degradation
of the response performance of the memory in the
processing of access or read/write to the utmost.

- 1 Moreover, since when ^{the remaining} a room of the redundancy becomes
small, the processing of access or read/write is
automatically stopped and the data reconstruction
processing is given preference, the reliability of the
5 memory is not reduced. Further, since the data reconstr-
uction processing method is changed according to the
^{time taken to reconstruct the faulty data} [accumulating totals of the data reconstruction proces-]
[sing time] of the storage units at fault, it is possible
7 to realize ^{the} memory of higher reliability. Moreover,
8 10 since the frequency of the data reconstruction proces-
sing or the ratio of the amount of the data reconstruc-
[within the unit time]
12 tion is set according to the magnitude of the frequency
of the processing of access or read/write, it is
possible to carry out the data reconstruction processing
15 effectively in a time aspect.